JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR VOLUME 5, NUMBER 2 APRIL, 1962

A FACILITATIVE EFFECT OF PUNISHMENT ON UNPUNISHED BEHAVIOR[1]

DALE M. BRETHOWER[2] AND G. S. REYNOLDS

HARVARD UNIVERSITY

The key pecking of two pigeons was reinforced on a variable-interval schedule of reinforcement during the presentation of each of two stimuli. In various phases of the experiment, punishment followed every response emitted in the presence of one of the stimuli. In general, when the rate of punished responding changed during the presentation of one stimulus, the rate of unpunished responding during the other stimulus changed in the opposite direction. This sort of change in rate is an example of behavioral contrast. When punishment was introduced, the rate of punished responding decreased and the rate of unpunished responding increased as functions of shock intensity. When the rate of previously punished responding increased after the termination of the shock, the rate of the always unpunished responding decreased. When the procedure correlated with a red key was changed from variable-interval reinforcement and punishment for each response to extinction and no punishment, the rate of reinforced responding during presentations of a green key decreased and then increased while the rate of the previously punished responding during red first increased and then decreased during extinction.

During the formation of a successive discrimination between a red key correlated with reinforcement and a green key correlated with extinction, a pigeon's rate of pecking the red key usually increases while its rate of pecking the green key decreases. This increase in the rate of reinforced pecking is opposite to the decrease predicted from an inhibitory induction (generalization), which has figured prominently in theories of discrimination. According to the theory, a decrease in the tendency to peck on a green key as a result of extinction should induce a decrease in the tendency to peck on a red key. (See Kimble, 1961, pp. 365-369.) On the contrary, the rate of pecking at red is usually increased. (See Reynolds, 1961b.) Hanson's (1959) data show that the increase also occurs for less different bands of wavelengths than those of red and green. Moreover, if pecking on green is reinforced or if the green key is no longer presented, the rate of pecking on red decreases nearly to the level prevailing before the discrimination was formed. Thus, the increase in red is a reversible change in the rate of maintained responding, and it is not due to additional experience with the procedure or to additional reinforcements. To distinguish it from induction, the increase has been called behavioral *contrast.* (See Reynolds, 1961a, Skinner, 1938.)

The data reported here show that punishment may also generate contrast. When each peck on a green key is punished with an electric shock, the tendency to peck at green is reduced, at least for a short time (Azrin, 1960). In the present data, the decreased rate of pecking on the green key was usually accompanied by an increased rate of unpunished pecking on an alternated red key.

METHOD

Subjects

Two adult, male, White Carneaux pigeons were maintained at about 80% of their free-feeding weights. Each pigeon had previously been reinforced on multiple schedules.

Apparatus

A standard experimental chamber (Ferster & Skinner, 1957) contained a response key operated by an effective force of about 15 g, provision for transilluminating the key with

[1]This research was supported in part by Grant G-8621 from the National Science Foundation to Harvard University, and was carried out while the senior author was a National Institutes of Health predoctoral fellow. Expenses of publication partly paid by NIH Grant M-5139.

[2]Now at the Language Laboratory, University of Michigan.

either red or green light, general white illumination, and a magazine for controlled presentation of grain (the reinforcer). White noise masked most extraneous sounds.

The punisher was electric shock, which could be delivered to the pigeons through gold electrodes secured to the pubis bone on each side of the bird. Azrin (1959) developed this technique. The pigeons were shocked for approximately 20 msec by imposing 115 v of 60-cycle, alternating current across a series circuit composed of the pigeon and a resistance. The current was varied by increasing or decreasing the resistance, and it was measured with a rectifier-type milliammeter.

Procedure

A daily experimental session consisted of 20 cycles of a two-component multiple schedule of reinforcement. Each cycle consisted of 3 min of red-key illumination followed by 3 min of green-key illumination. Key pecking was reinforced with access to grain for 3 sec on a variable-interval (VI) schedule both when the key was red and when it was green. A separate VI programmer was used for each component. The minimum average interreinforcement interval of both VI schedules was 3 min. When a reinforcer was programmed but not delivered during the presentation of one color, it was cancelled when the colors changed.

At various times throughout the series of experiments, each key peck during the presentations of the red key was punished with shock. The introduction or removal of different intensities of shock constituted the major experimental manipulation. Except for the last procedure, in which no reinforcers were programmed during red, pecking was always reinforced on VI 3 min during both red and green, whether or not pecking was punished. Table 1 shows the sequence of schedules and the intensities of punishment in milliamperes.

Table 1
Sequence of Schedules and Intensities of Punishment

	Number of Sessions	
Red Key, with VI 3 on Green Key	*Bird 144*	*Bird 152*
VI 3	10	8
VI 3 plus punishment, 3.6 ma	40	40
VI 3 plus punishment, 1.35 ma	9	16
VI 3	15	8
VI 3 plus punishment, 1.35 ma	11	11
VI 3 plus punishment, 2.5 ma	12	13
VI 3	7	7
VI 3 plus punishment, 2.5 ma	7	7
VI 3	8	7
VI 3 plus punishment, 3.6 ma	5	6
Extinction	12	12

RESULTS

Figure 1 shows the effects of the electric shock on the frequency of the punished key pecking. The ordinate is the total number of responses occurring during the presentation of the red key in the session listed on the abscissa. Session 0 is the last session before the introduction of the shock. Sessions 1 to 6 are successive sessions in which each response was punished. The labels of the curves give the intensity of the shock in milliamperes. There is one example of the effects of 1.35 and of 2.5 ma, and two examples of the effects of 3.6 ma. The figure shows that the frequency of punished responding decreases as the intensity of the shock increases. This result confirms the work of Azrin (1960), who studied the frequency of punished responding maintained by variable-interval schedules in isolation (not as components of a multiple schedule, as in the present experiment).

The changes observed in the rate of unpunished responding are the primary concern here. Figure 2 shows the per cent change in the rate of unpunished responding during the presentations of the green key before and after each response during red was punished. At Session 0, no responses were punished during the presentation of either color. In Sessions 1 to 7, punishment followed each response emitted during red. The labels of the curves in Fig. 2 give the intensity of the shocks delivered during red. The per cent change in the rate of unpunished responding during green was computed by dividing the number of responses in each of Sessions 1 to 7 by the average number of responses in Session 0 and the two preceding sessions.

Although the same schedule of reinforcement was always correlated with the green key, the rate of unpunished responding increased markedly during the presentation of green when punishment was delivered after each response during the presentation of red. After the initial increase, the curves in Fig. 2 approach a level that depends upon the intensity of the shock. The curves for the first introduc-

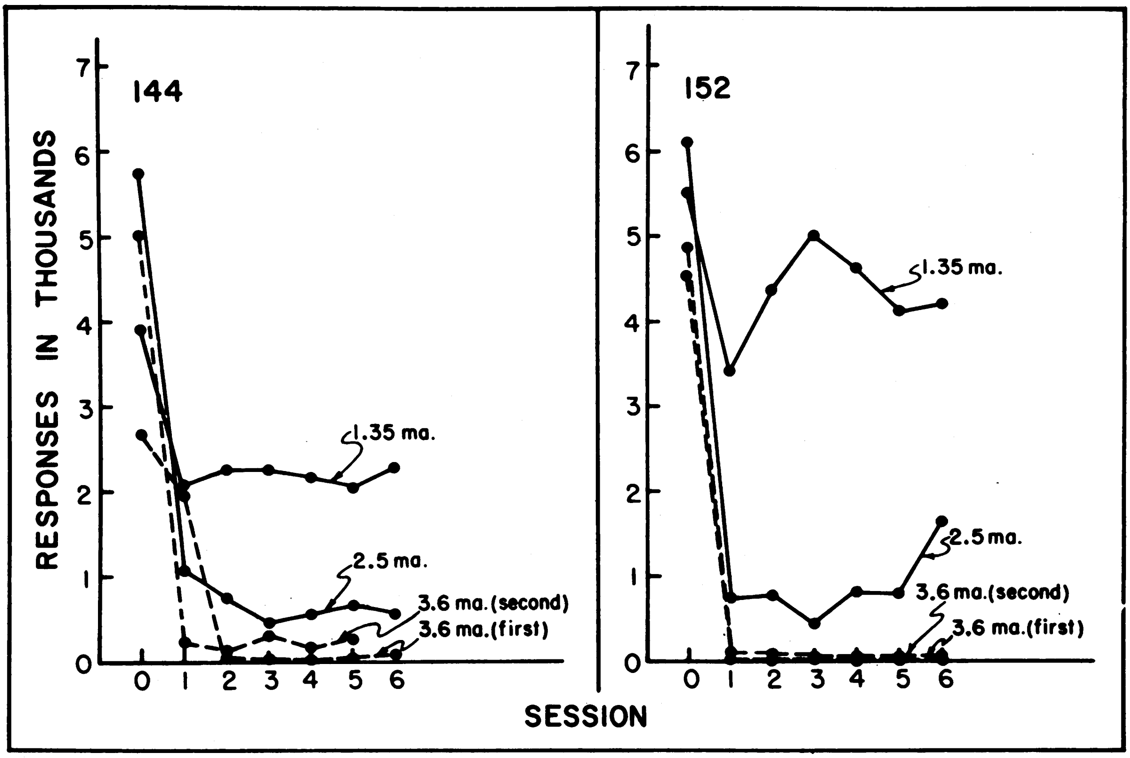

Fig. 1. The number of responses per session during the presentations of a red key. No responses were punished in Session 0. Every response was punished in Sessions 1 to 6. The curves are labeled according to the intensity of the punishment.

tion of punishment, at 3.6 ma, are not plotted because the first experience with punishment produced atypical effects. The rate of responding for Pigeon 144 increased to 140 per cent and then declined to an increase of about 90 per cent. The curve for Pigeon 152 decreased to minus 80 per cent before increasing to plus 20 to 30 per cent.

Plotting the per cent changes in the unpunished rate of responding superimposes the first points on each curve and allows direct comparisons among the magnitudes of the effects. However, the graph does not show the over-all upward shift in the base line after punishment was once introduced. The rate of unpunished responding during green decreased when punishment was removed during red, but it never decreased to what it had been before punishment was introduced (*cf.*, the relative magnitudes of positive and negative behavioral contrast, Reynolds, 1961a, 1961b).

The over-all increases in the rate of unpunished responding occurred in spite of a relative suppression in the rate during the latter part of the presentation of the green key. Figure 3 is a sample cumulative record showing the suppression. The record shows the responding of Pigeon 144 in the first session of the second introduction of punishment at 3.6 ma. Each response during red was punished. The recording pen was held down throughout the presentations of green. The record returns to the base line when the key lights changed to red. Reinforcements are indicated by diagonal strokes on the record. At the beginning of each 3-min presentation of the green key, the rate of unpunished responding is high. In the second or third minute, however, there is often a transition to a lower rate (as at A, B, and C on the record).

Figure 4 summarizes the per cent change in the rate of unpunished responding during green as a function of increasing intensity of shock during red. The points plotted are the terminal levels of the shock curves shown in Fig. 2 and Fig. 5. (See below.) A plot of the means or medians of the last sessions in the curves also shows the same relationship, a

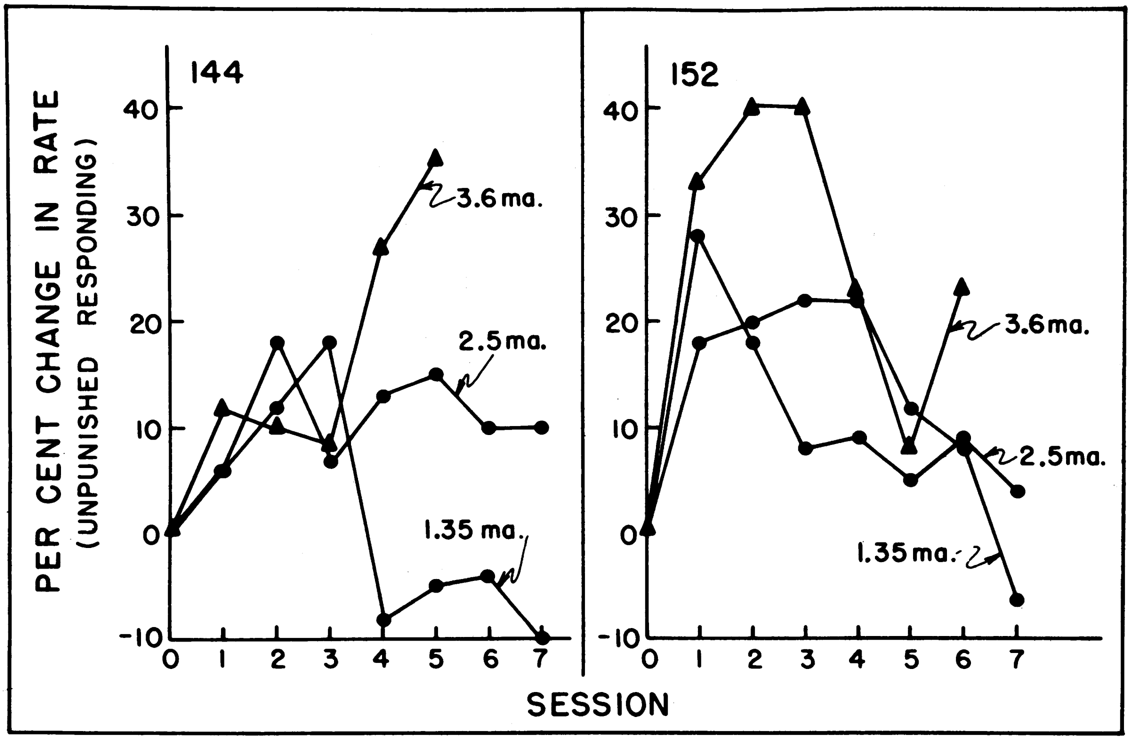

Fig. 2. The per cent change in the rate of unpunished responding during the presentations of a green key when no responses were punished during red (Session 0), and when every response was punished during red (Sessions 1 to 7). The labels show the intensity of the punishment delivered when the key was red.

greater per cent increase in rate with higher shock intensities.

Figure 5 shows the per cent change in the rate of unpunished responding during green when the intensity of the punishment during red is changed. The first number in the labels of the curves gives the intensity of shock during Session 0; the second number shows the intensity during Sessions 1 to 7. Note first the decline in responding when punishment is removed from the other component of the schedule, as in the curves labeled 2.5 ma to 0 ma and 1.35 ma to 0 ma. The curve for Pigeon 152 labeled 1.35 ma to 0 ma is an exception. There is a large increase rather than a decrease in responding.

When the shock intensity was decreased in red (curves labeled 3.6 ma to 1.35 ma), unpunished responding during green initially increased, then decreased. When the shock intensity increased from 1.35 ma to 2.5 ma, responding increased during the presentations of green.

When punishment was discontinued during red, the rate of responding during red immediately increased to a level above that of its previous unpunished one, and subsequently declined to approximately its usual, unpunished level. These changes during the presentation of red were accompanied by the changes in unpunished responding during green shown in the curves labeled "to 0 ma" in Fig. 5.

The decrease in rate of punished responding during the presentation of the red key resulted in a decrease in the frequency of reinforcement during red. Since a response was required for reinforcement, fewer reinforcers were presented if the response was delayed. When punishment was discontinued, the frequency of reinforcement during red increased. The effects of punishment were thus confounded with the effects of the changes in reinforcement frequency. The final procedure was designed to separate changes in the rate of responding during green due to changes in frequency of reinforcement during red from changes due to the presentation or removal of punishment during red. Consequently, both punishment and reinforcement were removed from red, whereas responding was reinforced

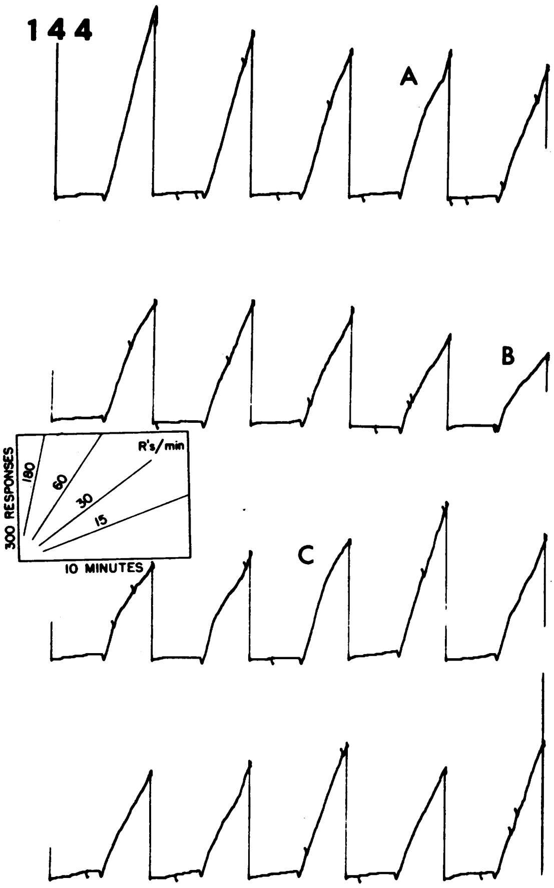

Fig. 3. Cumulative record of the responding of Pigeon 144 in the first session of punishment at 3.6 ma (second application) for every response emitted when the key was red. The recording pen is held down throughout the period when the key was green. The record returns to the base line when the key changes from green to red. Reinforcements are indicated by diagonal hashings on the records.

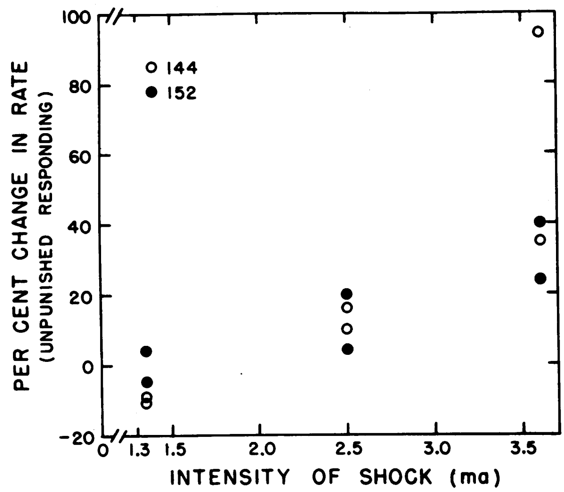

Fig. 4. The per cent change in the rate of unpunished responding during the presentations of green as a function of the intensity of the punishment delivered after every response emitted when the key was red.

as usual when the key was green. Figure 6 shows the results. The dashed curves show an increase and then a decrease in responding during red, where responding is no longer either punished or reinforced. The solid curves show a decline and then an increase in reinforced responding during green. Two changes in the procedure were correlated with the red key, and two different effects were noted on the responding during green. First, responding was no longer punished during red, and the rate of responding during green declined, as it does in the curves of Fig. 5. Second, the schedule of reinforcement during red was changed from VI 3 min to extinction. After the initial decline in the rate of responding during green with the removal of punishment from red (Sessions 1 to 4), the rate increased during green (Sessions 5 to 10). The increase is attributable to the change in the reinforcement schedule correlated with the red key. Changing one component of a multiple schedule from VI to extinction has been shown to produce increases in the rate of responding in an alternated VI component (*e.g.*, Reynolds, 1961a, which contains additional examples).

Figure 7 presents a useful summary of the relationship between the rate of unpunished responding during green and both the number of reinforcements per session received in red and the intensity of the punishment in red. The open points show the data of Pigeon 144, and the closed points show the data of Pigeon 152. Circles indicate a shock level of 3.6 ma; triangles, 2.5 ma; and squares, 1.35 ma. The graph shows the relative rate of unpunished responding during green as a function of the relative frequency of reinforcement during green. The ordinate is the number of responses per session during green divided by the total number of responses in that session. The abscissa is the number of reinforcements during green divided by the total number of reinforcements in the session. The ordinate value and the abscissa value for a given point were computed from the medians of the first seven sessions after punishment was introduced in red (or of the five sessions in one instance in which only five sessions were avail-

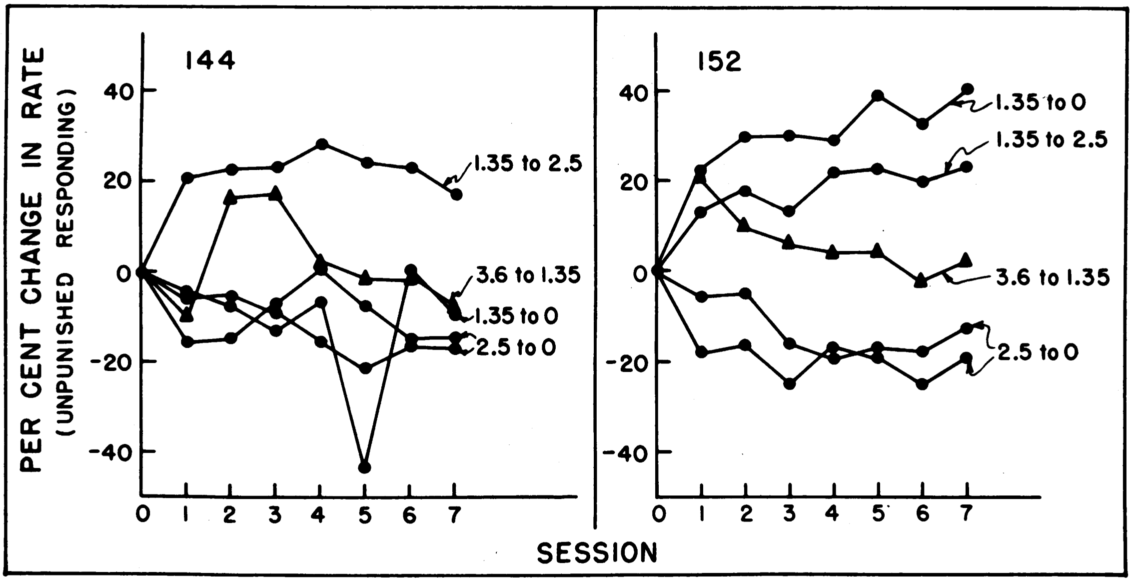

Fig. 5. The per cent change in the rate of unpunished responding during the presentations of the green key under the conditions given in the labels of the curves. The first intensity of punishment in the labels refers to Session 0; the second, to the subsequent sessions.

able). When there was no punishment, these points clustered around 0.5 on both the ordinate and the abscissa because the frequencies of both responses and reinforcements were approximately the same in each component.

The figure shows that the frequency of reinforcement as well as the intensity of the shock during red affected the relative rate of unpunished responding during green. A comparison of the ordinates for each shock intensity shows that the relative rate of responding during green is an increasing function of shock intensity. In three instances, identical relative frequencies of reinforcement were produced by different shock intensities. In each of these (0.5, 0.53, and 0.55 on the abscissa), the relative rate of responding was higher for the higher shock intensity.

There are two points per shock intensity for each pigeon. For each of these six pairs of points, the lower relative rate of responding is correlated with the lower relative frequency of reinforcement; and the higher relative rate of responding is correlated with the higher relative frequency of reinforcement. The relative rate of unpunished responding during green thus appears to be determined by both the relative frequency of reinforcement during green and by the intensity of the punishment delivered when the key was red.

DISCUSSION

The rate of unpunished pecking usually increased when each peck during the presentation of a different stimulus was punished. Azrin (1956, p. 17) has mentioned another example of behavioral contrast generated by punishment. The "compensatory increase" in the rate of responding following a conditioned aversive stimulus (Estes & Skinner, 1941) or following periods of punishment (Estes, 1944) may also be relevant. However, some experiments (*e.g.*, Dinsmoor, 1952) and some unpublished data by Reynolds on rats indicate that punishment may generate induction rather than contrast under certain conditions. The rate of responding decreases in the presence of each of two stimuli when responding is punished in the presence of only one. Since, as outlined above and elsewhere (Reynolds, 1961d), induction is accepted by traditional theories of discrimination, we may be allowed four speculations as to plausible reasons for the relative paucity of demonstrations of contrast with punishment. If we ignore the possibility that the effect of punishment on the behavior of rats and pigeons may be different, four speculations follow.

1. The observed decreases in the rate of responding may not be induction, a reduced

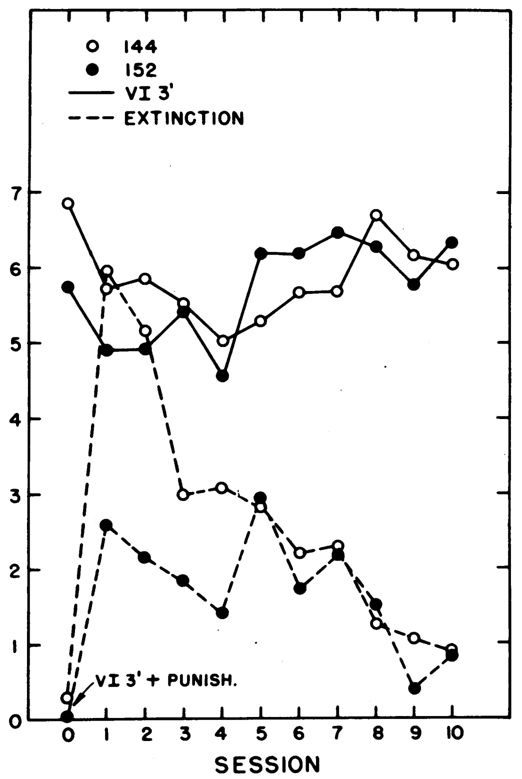

Fig. 6. Number of responses per session. Dashed lines show responding when the key was red. Each response in Session 0 was punished with a shock of 3.6 ma., and responding was reinforced on a variable-interval schedule. In Sessions 1 to 10, no responses were punished and no responses were reinforced. Solid lines: In every session, responding was reinforced on a variable-interval schedule when the key was green.

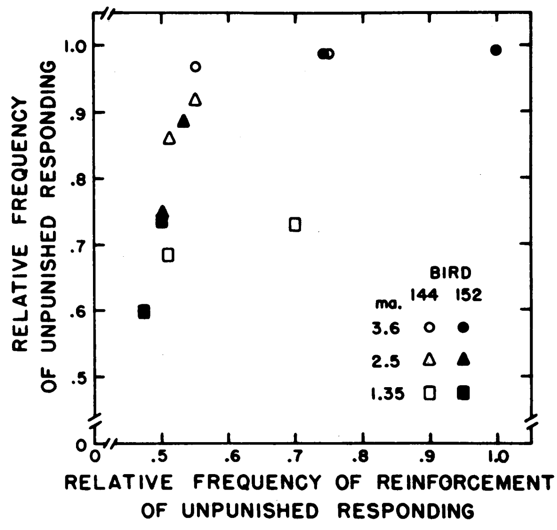

Fig. 7. The relative frequency of responding during presentations of the green key as a function of the relative frequency of reinforcement during green. The different symbols are explained in the key to the figure.

tendency to respond, but rather pseudo-induction due to a change in the topography of the response, limiting the rate of responding. Punishment may cause a change in the topography of the response, especially if it is delivered through ineffectively "scrambled" grids or through the manipulandum as one electrode. Such procedures may give the organism considerable control over the duration, magnitude, and bodily locus of the punisher, so that particular topographies resulting in less total punishment may be differentially reinforced. If these reinforced changes in topography continue under the unpunished condition, the response whose rate is measured may be an essentially different class of behaviors after punishment than before. The rates of the two responses cannot then be meaningfully compared. Such changes in topography would generally result in limitations on the rate of responding, thereby masking contrast. The net result could be, for example, a lower rate of lever pressing after punishment not because of a decreased tendency to press the lever (not because of competing behavior) but because of a change in the topography of lever pressing. Only the former is legitimately called induction. Azrin's method of punishing through permanently attached electrodes appears to successfully dispose of these difficulties by adequately controlling the punishing stimulus.

2. The initial effect of punishment may not be the same as its later effect. The appearance of contrast seems to depend upon continuing the experiment beyond the first one or two administrations of punishment. The first introduction of punishment for our Pigeon 152 (at 3.6 ma) produced induction, a temporary suppression of responding in the presence of both stimuli. But contrast, an increase in unpunished responding, appeared for 3.6 ma later in the series, after the pigeon was exposed to punishment several times, alternated with blocks of sessions in which no responses were punished. A speculation is that the initial, overall suppression is an emotional effect whose magnitude decreases with repetitions.

3. In a successive discrimination, contrast may be masked by a suppression of responding due to adventitious correlations of unpunished responses with the onset of the stimulus as-

sociated with punishment. Figure 3 shows such an effect. This suppression, if general, may occur at the end of a period of unpunished responding regardless of its duration. If so, increases in the duration of the stimuli would not change the present results, but decreases might obscure the effect entirely.

4. Like most other changes in responding during a discrimination, the development and magnitude of contrast with punishment probably depend on the physical difference between the stimuli, the animal's previous experience with them, and on the schedule of reinforcement maintaining the behavior. Since these variables were not studied here, their values may have been chosen fortuitously.

Can we account for the occurrence of contrast in the present experiments from known effects of positive reinforcers and aversive stimuli? Not easily. But the following is a discussion of some possibilities.

Apparently, neither the increases nor the maintenance of the increases in the rate of unpunished responding during the presentation of green can be explained by an appeal to possible changes in the consequences of responding during green. An interpretation of the increase in terms of an increase in the frequency of reinforcement of responses after relatively short inter-response times is weakened by the local suppression (Fig. 3), which tends to increase the frequency of reinforcement of responses occurring after relatively long inter-response times. An account of the high rate of unpunished responding early in the presentation of green in terms of punishment (by the onset of the stimulus correlated with shock) of relatively long inter-response times during the local suppression at the end of the presentation of green is implausible if we appeal to that same contingency in explaining the occurrence of the suppression in the first place. Moreover, a satisfactory account must explain the decline in rate during green after the removal of punishment from red; and the effect of removing punishment from red on the consequences of responding during green is the removal of the contingencies suppressing the rate of responding during the later part of the interval.

Nor does the increase in the rate of unpunished responding during green depend exclusively on a decrease in the number of reinforcements received during red, as previously reported examples of contrast (Reynolds, 1961c) may. This sort of variation occurred (Fig. 7), but the rate sometimes increased during green when the frequency of reinforcement during red did not change. (See Fig. 4 and 7.)

Figure 6 presents additional evidence that either punishment or a decrease in the frequency of reinforcement correlated with one stimulus is sufficient to produce contrast in the presence of a different stimulus. Changing the conditions correlated with red from reinforcement to extinction eventually produced an increase in the rate of reinforced, unpunished pecking during green, but only after the rate during green had declined because punishment was removed.

Perhaps punishment is functionally similar to a decrease in the frequency of positive reinforcement.

It may be useful to compare the present results with the changes in the rate of reinforced responding in one stimulus brought about by directly varying the frequency of reinforcement correlated with a different stimulus (Reynolds, 1961c). In that experiment, different relative frequencies of reinforcement were produced by changing the average value of a variable-interval, or the length of a fixed-ratio, schedule in one of two components of a multiple schedule. An analysis of the data was presented that is directly comparable to the present Fig. 7. The function described by the points on the previous graph appears to be a straight line of slope less than 1.0, with perhaps some upward concavity at relative frequencies of reinforcement greater than 0.8. The function in the present Fig. 7 is clearly concave downward, with an initial portion (0.45 to 0.55 on the abscissa) whose slope, if considered as linear, is greater than 4.0. These differences between the two functions show the effect of punishment in the present experiments. For a given relative frequency of reinforcement during green, punishment during red increases the relative rate of responding during green. This relative increase during green is jointly determined by a decrease in the rate of punished responding during red (Fig. 1) and by an increase in the rate of unpunished responding during green (Fig. 2).

REFERENCES

Azrin, N. H. Some effects of two intermittent schedules of immediate and non-immediate punishment. *J. gen. Psychol.*, 1956, **42**, 3-21.

Azrin, N. H. A technique for delivering shock to pigeons. *J. exp. Anal. Behav.*, 1959, **2**, 161-163.

Azrin, N. H. Effects of punishment intensity during variable-interval reinforcement. *J. exp. Anal. Behav.*, 1960, **3**, 123-142.

Dinsmoor, J. A. A discrimination based on punishment. *Quart. J. exp. Psychol.*, 1952, **4**, 27-45.

Estes, W. K. An experimental study of punishment. *Psychol. Monogr.*, 1944, **57**, Whole No. 263.

Estes, W. K., and Skinner, B. F. Some quantitative properties of anxiety. *J. exp. Psychol.*, 1941, **39**, 466-483.

Ferster, C. B., and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.

Hanson, H. Effects of discrimination training on stimulus generalization. *J. exp. Psychol.*, 1959, **58**, 321-335.

Kimble, G. A. *Hilgard and Marquis' Conditioning and Learning*, Ed. 2. New York: Appleton-Century-Crofts, 1961.

Reynolds, G. S. Behavioral contrast. *J. exp. Anal. Behav.*, 1961, **4**, 57-71. (a)

Reynolds, G. S. An analysis of interactions in a multiple schedule. *J. exp. Anal. Behav.*, 1961, **4**, 107-117. (b)

Reynolds, G. S. Relativity of response and reinforcement frequencies in a multiple schedule. *J. exp. Anal. Behav.*, 1961, **4**, 179-184. (c)

Reynolds, G. S. Contrast, Generalization, and the Process of Discrimination. *J. exp. Anal. Behav.*, 1961, **4**, 289-294. (d)

Skinner, B. F. *Behavior of organisms*. New York: D. Appleton Century Co., 1938.

Received August 5, 1961